Risk Factors for Mortality from Diarrhea in Beef Calves in Alberta

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ABSTRACT

A case-study involving 56 randomly selected beef herds in Alberta was conducted to assess the association of a number of suspected risk factors upon the odds of a high mortality from diarrhea among calves less than 30 days of age. Using stepwise logistic regression it was found that an increased percentage of heifers calving in the herd, poor drainage in the nursing area, providing limited shelter in the nursing area, a large calving area, and wintering cows and heifers on the same ground were conditionally associated with an increase in the odds of high mortality from neonatal diarrhea.

RÉSUMÉ

Une étude conduite en Alberta à partir de 56 troupeaux de bovins de boucherie a été menée afin de déterminer les relations entre les facteurs favorisant la diarrhée et les hauts taux de mortalité chez des veaux âgés de 30 jours et moins atteints de cette maladie. À l'aide d'une régression logistique, il a été démontré qu'un grand nombre de primipares, dans un troupeau, qu'un mauvais drainage et que peu d'abris dans l'aire où les vaches allaitent ainsi que le fait de ne pas séparer les vaches adultes des taures durant la période hivernale s'avèrent des facteurs importants retrouvés lors d'épisodes de diarrhée néontale avec les hauts taux de mortalité. ***(Traduit par Dr Pascal Dubreuil).***

INTRODUCTION

Diarrhea in beef calves less than 30 days of age is a major cause of neonatal mortality in western Canada (1,2). Over a three year period the average incidence of diarrhea, mortality and case fatality rates associated with diarrhea were 16.7%, 1.51% and 9.02% respectively in calves under 30 days of age (1). In another survey the incidence of neonatal diarrhea was 21.98%, with a mortality rate of 3.06% and a case fatality rate of 13.96% (2). In both surveys, between 70 and 80% of all herds experienced some diarrhea in the neonatal period but 65% of these herds had no mortalities from calf diarrhea.

The prevention of acute neonatal diarrhea in beef calves is difficult to achieve due to the large number of etiological agents and management factors that have been related to its occurrence. The incidence of diarrhea in beef calves may be reduced by increasing the specific resistance of newborn calves and by reducing the concentration of pathogens in the environment (3). The use of a vaccine against enterotoxigenic *Escherichia coli* gave effective protection against death from this organism in experimental and field studies (4,5). Recent vaccines against some viral agents have been shown to increase colostral antibody titers, produce seroconversion (6,7) and reduce the incidence of rotavirus diarrhea in field trials (6,8,9).

Little conclusive information has been published on the effect of various management practices upon the occurrence of death due to neonatal diarrhea in beef herds. The objective of this study was to evaluate the influence of a number of predetermined risk factors on the occurrence of a high mortality rate from neonatal diarrhea in beef cow-calf operations using the case-control study method.

MATERIALS AND METHODS

STUDY POPULATION

A survey was performed of beef cow-calf operations in the province of Alberta. The initial sampling units were the veterinary practices in the province that serviced beef cow-calf units. From the list of all veterinary practices with beef cow-calf clients, ten practices were randomly selected by means of a computerized random number generator. The practices were located in Bassano, Brooks, Innisfail, Lac La Biche, Mayerthrope, Peace River, Red Deer, Spruce Grove, Stettler and Wainwright. An alphabetically ordered list of all cow-calf clients was obtained from each practice. During the last three weeks of May 1988, every second cow-calf operation was contacted by telephone. During the telephone interview the number of cows calved and yet to calve, the number of calves born, the number of calves dead from diarrhea before 30 days of age and the approximate age when calves started to scour, was collected. In total, 686 farmers were contacted; approximately 50 of the selected farmers could

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not be reached or were no longer in the cow-calf business.

The mortality rate in each farming unit was calculated as the number of calves dying with diarrhea before 30 days of age divided by the total number of calves born. These results did not necessarily represent the final mortality rates because the calving season was not completed in a number of the operations and, at the time of the telephone interview, not all of the calves had reached 30 days of age.

Based on the data gathered during the telephone survey, a case-control study was designed to explore the relationship between the risk factors and the occurrence of a high mortality due to diarrhea on beef farms. A case was defined as a farm with a herd of 40 or more bred females and a mortality rate of greater than 4% from calf diarrhea in calves less than 30 days of age. Twenty-nine farms fulfilled these requirements. The owner of one case farm was not prepared to participate in a personal interview and this farm was eliminated from the study. Twenty-eight control farms were randomly selected from farms with a herd size of 40 or more females and a 0% mortality rate from calf diarrhea in calves less than 30 days of age at the time of the telephone interview. To reduce potential confounding every case farm within a given veterinary practice was matched with a control farm that was randomly selected from the farms in the same practice.

The mortality rate from diarrhea in calves less than 30 days in all farms was recalculated using the data from the final questionnaire. One of the case farms was eliminated from the study because the mortality rate of 1.15% was inconsistent with that given during the telephone survey. In four other case farms, the mortality rate dropped from above 4% at the time of the telephone interview to just below 3%. In two control farms the mortality rate increased to 1.16 and 1.72% respectively. For the final analysis, case farms were defined as those farms having 40 or more bred females and a diarrhea specific mortality rate in calves younger than 30 days of age greater than 4% based upon the telephone interview and greater than 2% based upon the personal interview. A control farm was defined as a farm with a herd of 40 or more bred females, a mortality rate due to diarrhea in neonatal calves of 0% based upon the telephone interview and less than 2% based upon the personal interview.

DATA COLLECTION

All farms were visited during the month of June 1988. A personal interview was conducted using a 48-question survey on factors related to the management of the cow-calf herd before, during and after calving. In the majority of interviews neither the facilities nor the cattle were seen. After completion of the interviews the questionnaires were coded, the data entered into a computer and the database checked against the original records. A copy of the questionnaire may be obtained from the senior author.

DATA ANALYSIS

The Statistical Analysis System (10) was used to verify the data, generate the descriptive statistics and assess the normality of the distributions of the continuous variables.

The number of calving and nursing areas used during the 1988 season varied from one to five per farm. Based upon the number of cows, weighted averages for the total area, shelter area and the area poorly drained were calculated for the calving and nursing areas. The number of first calf heifers in the herd was expressed as a percentage of the total number of females in the herd. In assessing the effects of wintering and calving heifers and cows together, farms without heifers were classified with those farms that did not winter and calve cows and heifers together. Colostrum intake was subjectively judged on a description by the farmer as to how he evaluated the intake of colostrum for each calf.

Pooled variance Student's *t*-tests for continious variables and the chi-square analysis for categorical variables were performed to measure the simple associations between the risk factors listed in Table I and the occurrence of a high rate of neonatal mortality in beef herds (10).

Stepwise, logistic regression was used to examine the combined effects of a set of *a priori* hypotheses upon a high mortality rate from diarrhea in neonatal calves (11). The variables representing the set of *a priori* hypotheses are indicated by an asterix in Table I. Variables were allowed to enter the logistic model if they explained a significant portion of the variation with a $p < 0.10$. The p-value for removal of variables from the model was set at $p > 0.10$. Brown's statistic was used to assess the adequacy of the logistic model for the data. The Hosmer-Lemeshow goodness of fit chi-square statistic was calculated to evaluate how well the data fit the model.

RESULTS

SIMPLE ASSOCIATIONS

The simple associations between each variable of interest and the occurrence of a high mortality due to calf diarrhea are presented in Tables II and III. The odds of a high mortality due to diarrhea was 3.6 times greater on farms that wintered cows and heifers together as compared to those farms where these groups were wintered separately. Wintering and calving animals on the same ground increased the odds of a high mortality from diarrhea by a factor of 3 ($p = 0.08$). Farms buying replacement calves less than four weeks of age for cows who lost their calves had a 4.3 times greater odds of high mortality compared to farms not buying young calves.

The percentage of heifers in the herd was significantly greater in case as compared to control herds ($p = 0.003$). Case herds had an average of 23% heifers as compared to 13% in control herds. On average, calving on case farms began two weeks in advance of calving on control farms ($p = 0.06$). The mean duration of the calving season on case farms was 86 days as compared to 58 days on control farms ($p = 0.002$). An increase in the percentage of the nursing area that was poorly drained was associated with an increase in the probability of a high mortality from diarrhea ($p = 0.08$).

In case farms the first calf started scouring after a mean of 33 cows had calved with an overall morbidity rate of 34% compared to 10% in control herds, where diarrhea occurred after a

TABLE I. Description and definition of variables used in the analysis of data related to diarrhea mortality in 55 case and control farms

Variable	Definition
Total animals[a]	Total number of females calving in the 1988 season
New heifers	Total number of heifers introduced on to the farm between breeding and calving
Heifer percentage[a]	The percentage of heifers in the cow herd
E. coli vaccination[a]	*Escherichia coli* vaccination status prior to the start of the calving season yes = vaccination no = no vaccination
Viral vaccination[a]	Rota/corona vaccination status prior to the start of the calving season yes = vaccination no = no vaccination
Vitamin supplementation[a]	Cows and heifers received supplemental vitamin A, D, E in the feed and/or by injection during the winter yes/no
Cows and heifers wintered on the same ground[a]	Cows and heifers wintered on the same ground yes/no
Animals wintered and calved on the same ground[a]	Animals wintered and calved on the same ground yes/no
Cows and heifers calved on the same ground[a]	Cows and heifers calved on the same ground yes/no
Calving started[a]	The date when the first calf was born
Calving season length	The number of days until 90% of animals had calved as an indicator of the length of the calving season
Calving area[a]	Calving area per cow in square metres
Poor drainage in calving area[a]	The percentage of the calving area poorly drained for more than three days
Shelter area in calving area[a]	The shelter area per cow in square meters in the calving area
Calving stay[a]	The number of days animals stayed in the calving area after they calved
Nursing area[a]	Nursing area per cow in square meters
Poor drainage in nursing area[a]	The percentage of the nursing area poorly drained for more than three days
Shelter area in nursing area[a]	The shelter area per cow in square meters in the nursing area
Colostrum intake[a]	good = calves received adequate colostrum within 6 h after birth questionable = calves did not receive adequate colostrum within 6 h after birth
Replacement calves	Farmers bought calves less than four weeks of age from auction market or dairies yes/no
# cows calved diarrhea started	The number of cows that had calved before the first calf scoured
Total diarrhea morbidity rate	The overall morbidity rate from diarrhea on each farm (%)
Total morbidity rate < 10 d	The overall morbidity rate from diarrhea in calves less than ten days of age (%)
Heifer diarrhea morbidity rate	The morbidity rate from diarrhea in calves born to heifers (%)
Cow diarrhea morbidity rate	The morbidity rate from diarrhea in calves born to cows (%)
Total diarrhea mortality rate	The overall mortality rate from diarrhea on each farm (%)
Total mortality rate < 10 d	The overall mortality rate from diarrhea in calves less than ten days of age (%)
Heifer diarrhea mortality rate	The mortality rate from diarrhea in calves born to heifers (%)
Cow diarrhea mortality rate	The mortality rate from diarrhea in calves born to cows (%)

[a]Variables used in the logistic regression analysis

mean of 70 cows had calved. Twenty-two percent of calves in case farms scoured before ten days of age whereas control farms only had a 4% morbidity rate from diarrhea in the same time span. In case farms 51% of the calves born to heifers scoured compared to 28% of the calves born to cows. The same trend was seen in the control herds with 20% and 8% of the calves scouring respectively. The overall mortality rate from diarrhea in case farms was 6.24% compared to 0.14% in the control herds during the first thirty days of life. During the first ten days of life 4.42% of calves born on case farms died from neonatal diarrhea, while 0.08% of calves on control farms died during the same time period ($p < 0.0001$). Calves born to heifers had a 14.88% mortality in comparison to 4.27% in calves born to cows in case herds ($p < 0.06$). In control farms the respective values were 0.44% and 0.07% ($p > 0.1$).

CONDITIONAL ASSOCIATIONS

The variables made available for selection in the logistic regression model were selected to test a set of *a priori* hypotheses which were based on recommendations that are commonly made to beef cow-calf producers who wish to reduce the morbidity and mortality of neonatal diarrhea. Due to the presence of some missing values associated with these variables two case and two control farms were lost from the analysis. The final analysis was based upon data from 25 control and 26 case farms.

The variables entering the final model for predicting the likelihood of a calf diarrhea mortality problem are listed in Table IV. Wintering cows and heifers on the same ground conditionally increased the odds of high mortality by 6.5 times (OR = 6.47, $p = 0.05$). An increase in the percentage of the heifers in the herd (OR = 1.21, $p = 0.01$), the size of the calving area available per cow (OR = 1.001, $p = 0.03$) and the percentage of the nursing area that was poorly drained (OR = 1.43, $p = 0.004$) also increased the odds of being a case farm. Increasing the amount of shelter per cow-calf pair in the nursing area was conditionally associated with a decrease in the odds of high mortality (OR = 0.998, $p = 0.006$).

The final model is summarized in Table V. The p-value for the Brown statistic ($p = 0.84$) indicated that the logistic model was appropriate for the data. The Hosmer-Lemeshow goodness of fit chi-square had a p-value of 0.42, indicating that the predicted values fit the data moderately well.

DISCUSSION

The telephone survey proved effective in reaching a random sample of the beef cow-calf clients suitable for selection as study subjects in the subsequent case-control study. The farms with a mortality rate above 4% from neonatal diarrhea represented only 4% of the 686 farms surveyed. The farms with a mortality rate of 0% from diarrhea represented 79% of the farms contacted by telephone and the remaining 17% of farms had a mortality rate between 0% and 4% due to diarrhea.

TABLE II. Categorical variables related to diarrhea mortality in 55 case and control farms

Variable	Cases[a]	Controls[a]	OR[b]	95% CL[c]	p value
E. coli vaccination					
yes	4	6	0.64	0.16, 2.57	ns[d]
no	23	22			
Viral vaccination					
yes	3	6	0.46	0.10, 2.06	ns[d]
no	24	22			
Vitamin supplementation					
yes	23	27	0.21	0.02, 2.04	0.19[d]
no	4	1			
Cows and heifers wintered on the same ground					
yes	18	10	3.60	1.18, 10.95	0.04
no	9	18			
Animals wintered and calved on the same ground					
yes	18	II	3.09	1.03, 9.31	0.08
no	9	17			
Cows and heifers calfed on the same ground					
yes	13	10	1.67	0.57, 4.92	ns
no	14	18			
Colostrum intake					
good	22	27	0.16	0.02, 1.50	0.10[d]
questionable	5	1			
Replacement calves					
yes	13	5	4.27	1.25, 14.57	0.04
no	14	23			

[a]Cases are the number of farms with a mortality rate from diarrhea $\geq 2\%$. Controls are the number of farms with a mortality rate from diarrhea $< 2\%$

[b]OR = adjusted odds ratio with the OR of the comparison category set equal to 1. Values greater than 1 indicates the factor predisposes to death from calf diarrhea, values less than 1 indicate a sparing effect

[c]CL = 95% precision based confidence limits for the odds ratio

[d]p value calculated by Fischer's exact test

ns = Nonsignificant at a p-value > 0.2

SIMPLE ASSOCIATIONS

Parenteral vaccination of pregnant females in the last trimester against *Escherichia coli* and/or viral diarrhea was not associated with a significant decrease in the odds of a high mortality rate from diarrhea in calves less than 30 days of age. However our study was not suited for the examination of this relationship. A larger study that accounted for the influence of mortality rate on individual farms in previous years would be required to adequately assess the effect of vaccination. In other experimental and field trials the parenteral immunization of the pregnant dam with *Escherichia coli* antigens increased colostral and milk antibody levels and protected the nursing calves against *Escherichia coli* diarrhea (4,5,12,13). Under experimental conditions, passive immunity did protect neonatal calves from viral diarrhea (14,15). Earlier field trials showed varying results with a viral vaccination program in pregnant dams (6,16), but the most recent European vaccines reduced the occurrence of rotavirus diarrhea in field trials (6,8,9).

Wintering cows and heifers on the same ground was associated with an increase in the odds of being a case farm. Calving on the wintering ground was also more common on case farms. These two practices tended to be employed together and it seems probable that this combination lead to increased levels of contamination on the calving ground prior to or early in the calving season. Considered by itself, the practice of calving cows and heifers together also tended to increase the odds of being a case farm but this association was not statistically significant. The reason that this association was not significant may be due to the fact that some farms that calved cows and heifers together did not follow the practices of calving on the wintering ground and/or wintered cows and heifers together.

Numerous studies demonstrated a relationship between the morbidity and mortality from neonatal calf diarrhea and an adequate early intake of colostrum (17-20). The passive transfer of colostral immunoglobulin is influenced by the mass of immunoglobulin fed (21), the volume of colostrum ingested with low immunoglobulin concentrations and the time after birth to first colostrum intake (21). The sucking drive and vigor of the calf, the conformation of the udder and teats and poor mothering influence the effective intake of adequate colostrum (21). In this study adequate colostrum intake tended to decrease the odds of mortality from diarrhea ($p = 0.10$). Failure to detect a more significant association between colostral intake and mortality may be due to the relatively crude definition of this variable in our study.

The introduction of replacement calves less than four weeks of age was associated with an increase in the odds of high mortality from diarrhea by a factor of 4.3. Newly introduced calves may have increased the level of contamination in the calving or nursing areas, resulting in an outbreak of diarrhea. Alternatively, farmers with calves dying from diarrhea may have been more likely to buy replacements.

This study did not support an earlier survey indicating that diarrhea is more likely to occur in larger herds (2). An early start as well as a longer calving season increased the likelihood of being a case farm. It is probable that early calving is associated with colder weather conditions on farms in western Canada. Exposure to cold probably results in increased stress and overcrowded shelter areas. An extended calving season should result in increased accumulation of manure and contaminated bedding thus increasing the risk of infection. It was also interesting to note that cases of diarrhea tended to occur earlier in the calving season on case farms than on control farms. Early contamination of the calving area by diarrheic calves would be expected to lead to a greater number of newborn calves being exposed and thereby increasing the risk of disease in this circumstance.

CONDITIONAL ASSOCIATIONS

The application of management principles to the prevention and control of undifferentiated neonatal diarrhea in the beef herd has been suggested (3), even though we do not have definitive evidence of many of the epidemiological factors contributing

TABLE III. Continuous variables related to diarrhea mortality in 55 case and control farms

Variable	N[a]	Mean	SD[b]	Range Min	Range Max	p value
Total animals						
cases	27	125	81	38	348	ns
controls	28	112	74	40	310	
New heifers						
cases	26	14	22	0	90	0.14
controls	22	6	13	0	50	
Heifer percentage (%)						
cases	27	23	14	0	53	0.003
controls	28	13	9	0	30	
Calving started (date)						
cases	27	7/2/88	26	20/12/87	5/4/88	0.06
controls	28	21/2/88	25	20/11/87	30/3/88	
Calving season length (days)						
cases	23	86	34	26	157	0.002
controls	28	58	20	31	116	
Calving area (m^2)						
cases	27	1448	2453	23	10653	0.16
controls	28	700	1174	13	4991	
Poor drainage in calving area (%)						
cases	27	9	18	0	90	ns
controls	27	10	13	0	44	
Shelter area in calving area (m^2)						
cases	27	231	518	0	2195	ns
controls	28	138	340	0	1623	
Calving stay, days						
cases	27	34	38	1	129	ns
controls	28	24	28	1	90	
Nursing area (m^2)						
cases	27	2810	3765	23	16745	ns
controls	28	3842	5412	56	28233	
Poor drainage in nursing area (%)						
cases	26	10	18	0	90	0.08
controls	28	3	6	0	26	
Shelter area in nursing area (m^2)						
cases	26	388	582	1	1831	0.11
controls	27	844	1325	0	5929	
# cows calved diarrhea started						
cases	26	33	29	0	130	0.002
controls	19	70	45	28	224	
Total diarrhea morbidity rate (%)						
cases	26	34	23	13	97	0.0002
controls	28	10	20	0	76	
Total morbidity rate < 10 d (%)						
cases	26	22	19	0	79	0.000!
controls	28	4	9	0	43	
Heifer diarrhea morbidity rate (%)						
cases	25	51	32	0	100	0.002
controls	22	20	34	0	100	
Cow diarrhea morbidity rate (%)						
cases	26	28	25	0	100	0.002
controls	28	8	18	0	74	
Total diarrhea mortality rate (%)						
cases	27	6.24	3.05	2.21	16.28	0.0001
controls	28	0.14	0.42	0	1.72	
Total mortality rate < 10 d (%)						
cases	27	4.42	3.25	0	13.95	0.0001
controls	28	0.08	0.28	0	1.16	
Heifer diarrhea mortality rate (%)						
cases	26	14.88	15.14	0	50	0.0001
controls	22	0.44	1.67	0	7.69	
Cow diarrhea mortality rate (%)						
cases	27	4.27	3.38	0	14.29	0.0001
controls	28	0.07	0.27	0	1.25	

[a]N is the number of farms used to calculate the different indices
[b]Standard deviation
ns = Nonsignificant at a p-value > 0.2

to the syndrome. The factors tested in the logistic regression analysis were selected because they represent some of the more common practices recommended to farmers in order to reduce the risk of diarrhea.

Stepwise logistic regression selected five variables from among those listed in Table I to distinguish between affected and unaffected farms. The percentage of first calf heifers in the herd was selected first. The odds ratio indicated that, with every percent increase in the number of heifers in the herd, the farm would be 1.2 times more likely to have a mortality rate from neonatal diarrhea above 2%. In this study the morbidity and mortality rate from diarrhea during the first 30 days of life in case farms in calves born to heifers was 51% and 14.8% respectively compared to 28% and 4.3% in the calves born to cows. In the control farms the morbidity and mortality rate from diarrhea in calves born to heifers was 20% and 0.44% respectively compared to 8.2% and 0.07% for the calves born to cows. Acres also showed a higher morbidity and mortality rate from diarrhea in calves born to heifers (26.9% and 3.7%) than in calves born to cows (14.4 and 1.17) (1).

There are several possible explanations for a higher mortality rate in calves born to heifers. Heifers are probably more closely confined during the calving season for better observation and faster assistance at parturition. These conditions may lead to increased contamination of the environment, belly and udder, and thus place newborn calves at greater risk. Closely confined calves born to heifers may also have difficulty locating and nursing their dams (1). In addition, heifers have a higher dystocia rate (22) which will result in an increase in exhaustion, weakness and swollen tongues in their calves. All of these conditions would be expected to make nursing more difficult (1,23). Heifers generally produce a lower volume of colostrum than older cows, and the quality of the colostrum is often inferior to that of cows (24). One study showed that approximately an equal percentage of cows and heifers shed virus but that a higher percentage of calves born to these heifers developed signs of diarrhea (25). A

TABLE IV. Variables related to mortality from calf diarrhea in the final model

Variable	B[a]	OR[b]	95% CI[c]		p value
Heifer percentage	0.188	1.21	1.04,	1.39	0.009
Calving area	0.000655	1.001	1.00004,	1.0013	0.03
Poor drainage in nursing area	0.358	1.43	1.118,	1.834	0.004
Shelter area in nursing area	-0.00152	0.998	0.997,	0.999	0.006
Cows and heifers wintered on the same ground	1.867	6.47	0.909,	46.00	0.049

[a]Estimated regression coefficient
[b]Adjusted odds ratio (OR = exp B)
[c]95% confidence limits for the odds ratio
(95% CI = exp(B ± 1.96* SE B)

TABLE V. The logistic regression model for predicting high neonatal mortality from diarrhea

y[a] = -5.87 + 0.188 heifer percentage + 0.000655 calving area + 0.358 poor drainage in nursing area - 0.00152 shelter area in nursing area + 1.867 cows and heifers wintered on the same ground

N = 51
HLGOFX^2 [b] = 8.123 p = 0.422
BGOFX^2 [c] = 0.339 p = 0.844

[a]y represents the predicted log odds of being a case
[b]Hosmer-Lemeshow goodness of fit chi-square
[c]Brown goodness of fit chi-square

high incidence of severe diarrhea in calves born to heifers may result in marked environmental contamination and this may increase the risk of disease in calves born to cows that are pastured in the same area.

As the proportion of the nursing area which was poorly drained, wet and muddy increased, so did the odds of that farm becoming a case. For every 1% increase in the area that was poorly drained there was a 1.4-fold increase in the odds of experiencing high mortality from calf diarrhea. As case and control farms were matched within veterinary practice, the amount of rain and snow on these farms should have been similar. A poorly drained area is likely to support the survival of pathogens and to increase the amount of contamination of the nursing area.

Increasing the shelter area in the nursing area helped protect against calf diarrhea. The shelter area provided space for both cows and calves. Shelter areas are especially important for the calves which tend to lie down frequently during the first two weeks of life. Small shelters tend to become crowded during bad weather. This leads to increased opportunities for disease transmission. Calves with no shelter available will be more exposed to inclement weather and tend to spend more time lying down and less time nursing.

The finding that large calving areas were associated with a high risk of mortality from diarrhea was unexpected. The mean calving area in the case farms was twice as large as the mean calving area in the control farms. It is generally recommended that the cow herd be kept as widely dispersed as possible during the calving season in order to reduce environmental contamination and the risk of pathogen transmission (3). There are two possible reasons why an increased calving area apparently predisposed to a higher risk. Firstly, cows may not have used all of the calving area. This will happen if animals are only bedded and fed on one spot in the calving area or when snow is not cleared adequately. It is also possible that farmers experiencing an increased incidence of diarrhea in their calves may have dispersed the animals in an attempt to control the disease.

Farms wintering cows and heifers together were 6.4 times more likely to have a high mortality rate from diarrhea. It is commonly recommended that producers winter their heifers and cows separately and the results of this study support that recommendation. Heifers wintered separately can be managed better to achieve their target calving weights. The volume of colostrum production is strongly influenced by the nutrition during late pregnancy (26,27). As well, wintering cows and heifers together was highly and positively correlated (p = 0.0001) with calving cows and/or heifers on the wintering ground. This procedure is likely to result in increased contamination of the calving ground.

In summary, we conclude that an increased percentage of heifers calving in the herd, providing limited shelter in the nursing area, an increased percentage of poorly drained ground in the nursing area, and wintering cows and heifers on the same ground were associated with an increase in the odds of high mortality from neonatal diarrhea.

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